HYDRO-ELECTRIC INQUIRY COMMISSION

GENERAL REPORT

THE QUEENSTON-CHIPPAWA POWER DEVELOPMENT

WATER AVAILABLE USAGE COST.

VOLUME I —HISTORY AND DESCRIPTION
✓ VOLUME II —COST, CAPACITY AND OPERATION
VOLUME III—ESTIMATES AND APPROPRIATIONS
VOLUME IV—REASONS FOR INCREASED COST

SEE P 133 - 141

VOLUME II

JOSEPH H. W. BOWER
SECRETARY

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OF

THE QUEENSTON-CHIPPAWA POWER DEVELOPMENT

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THE QUINNESTON-CHIPPAWA POWER DEVELOPMENT

VOLUME II

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PART V - QUANTITIES AND COSTS

Section 23

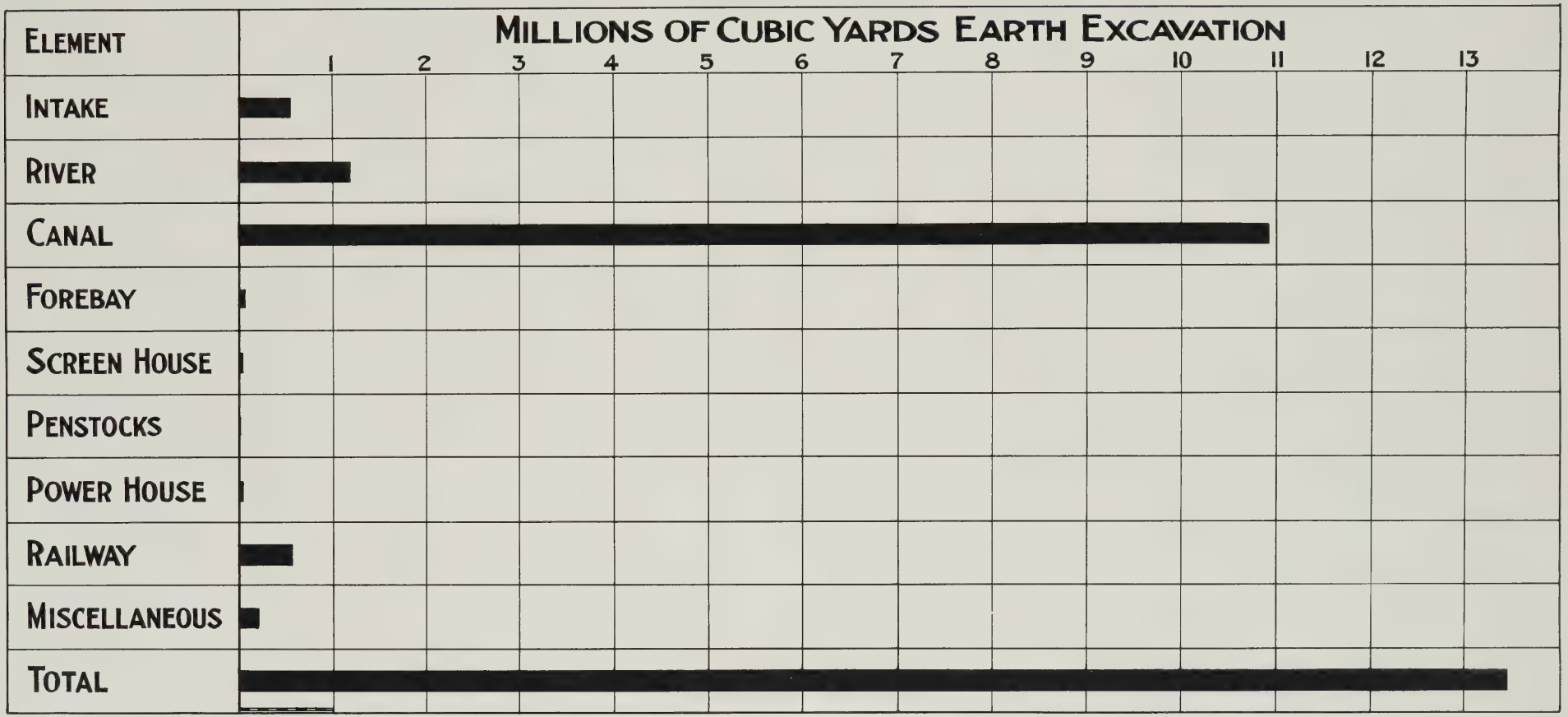
SUMMARY OF QUANTITIES

Our Consulting Engineer has discussed quantities and costs in detail in Chapter XV of his report.

We include as pages 121, 122 and 123 charts showing the cubic yards of earth and rock excavated in the various elements of the work and the amount of concrete placed, classified under group headings.

Dealing only with earth and rock excavation it will be noted that the canal constituted by far the most important element in the work. Out of the total earth excavation of 13,500,000 yards, almost 11,000,000 yards came from the canal. Similarly in the matter of rock excavation out of a total of 4,750,000 yards, 3,750,000 yards came from this section of the work.

The quantities of concrete in the canal section bear a similar relationship to the total amount of concrete placed in the whole undertaking. Out of a total of about 370,000 cubic yards, over 300,000 cubic



HYDRO-ELECTRIC INQUIRY COMMISSION

W. D. GREGORY, CHAIRMAN

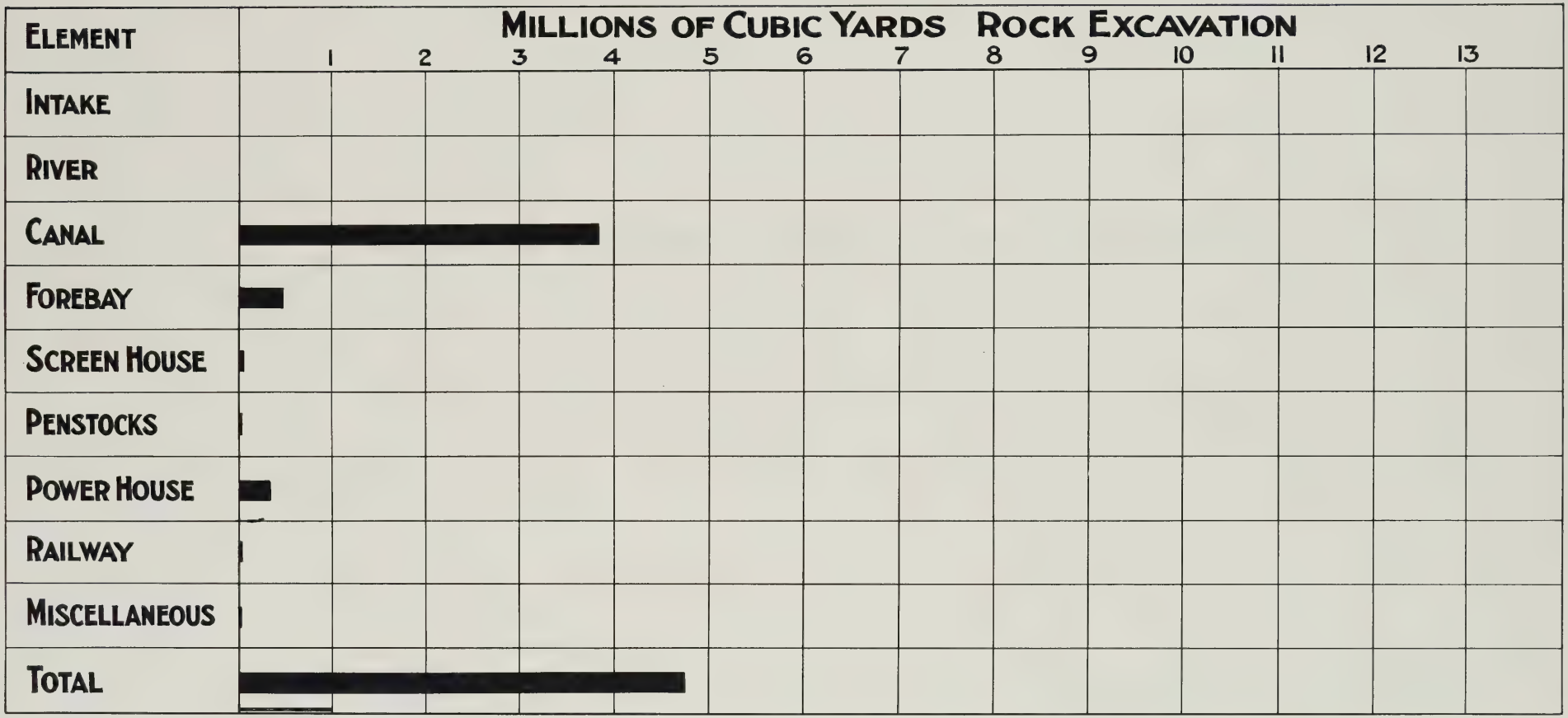
QUEENSTON-CHIPPAWA POWER DEVELOPMENT

DISTRIBUTION CHART OF EARTH EXCAVATION IN CANAL AND FOREBAY

Toronto, May 3rd, 1923. Made by G.B.C. Checked by W.J.F.

WALTER J. FRANCIS & COMPANY

CONSULTING ENGINEERS



HYDRO-ELECTRIC INQUIRY COMMISSION

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QUEENSTON-CHIPPAWA POWER DEVELOPMENT

DISTRIBUTION CHART OF ROCK EXCAVATION IN CANAL AND FOREBAY

Toronto, May 3rd, 1923. Made by G.E.B. Checked by W.J.F.

WALTER J. FRANCIS & COMPANY

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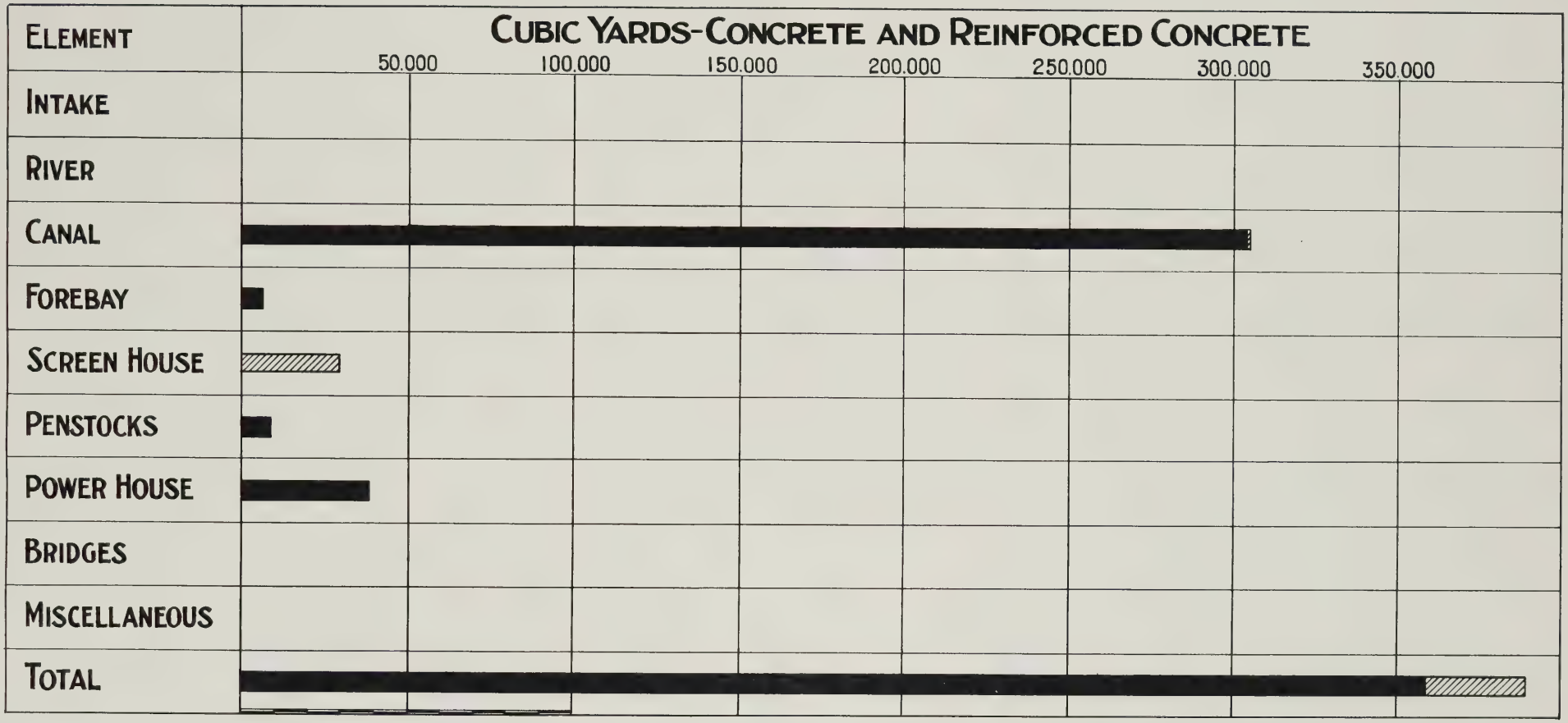


CONCRETE

REINFORCED CONCRETE

HYDRO-ELECTRIC INQUIRY COMMISSION

W. D. GREGORY, CHAIRMAN

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

DISTRIBUTION CHART OF CONCRETE WORK IN CANAL AND FOREBAY

Toronto, May 3rd, 1923. Made by G.E.B. Checked by W.J.F.

WALTER J. FRANCIS & COMPANY

CONSULTING ENGINEERS

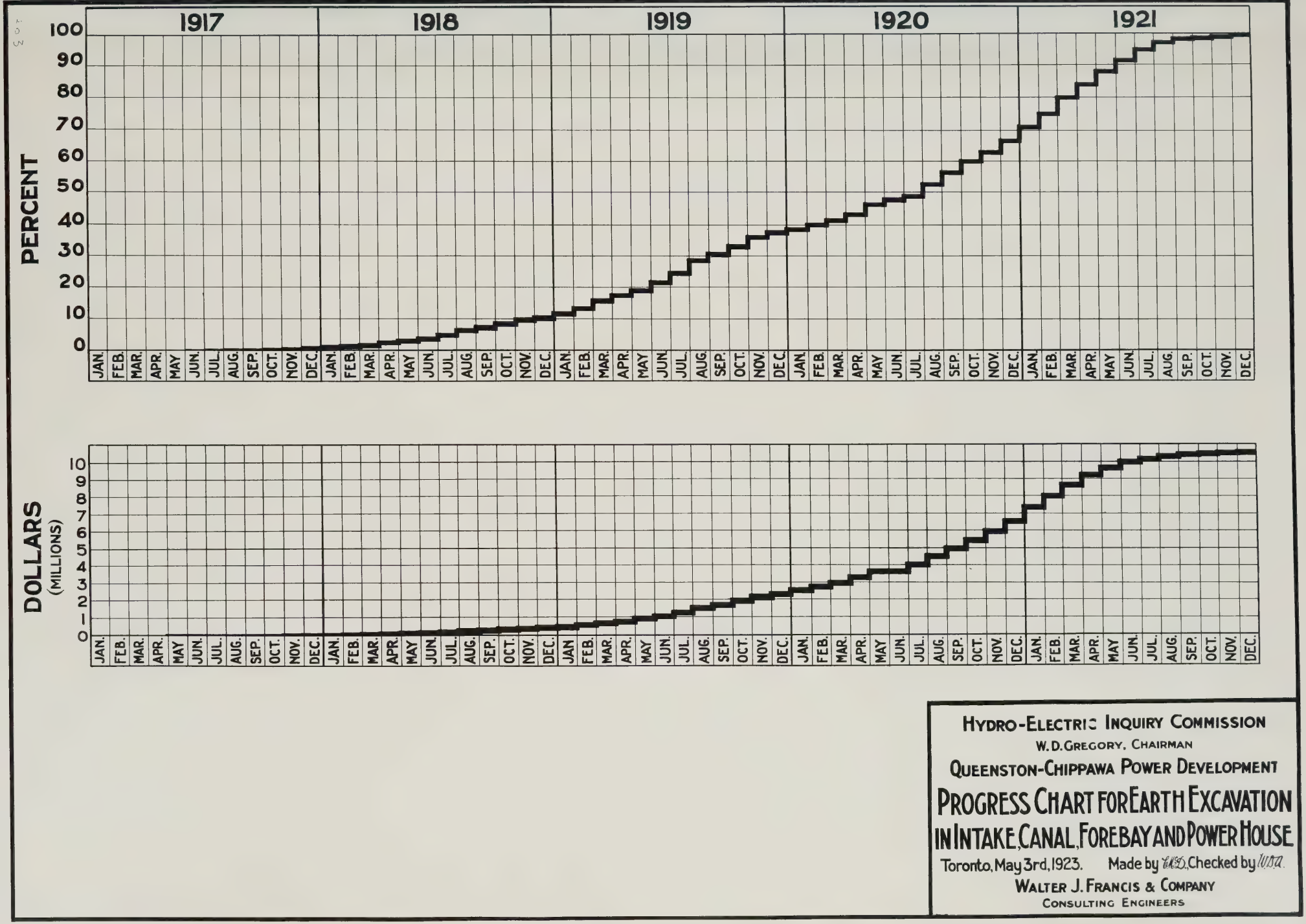
yards were placed in the canal section. The relative importance of the canal section proper is, therefore, apparent and when reading the later sections of our report this fact should be kept in mind. We will deal later in detail with the rate of progress on the various parts of the work, but we include herewith as pages 125, 126 and 127 progress charts showing the rate at which the earth and rock excavation and concrete work was done during the entire period of construction.

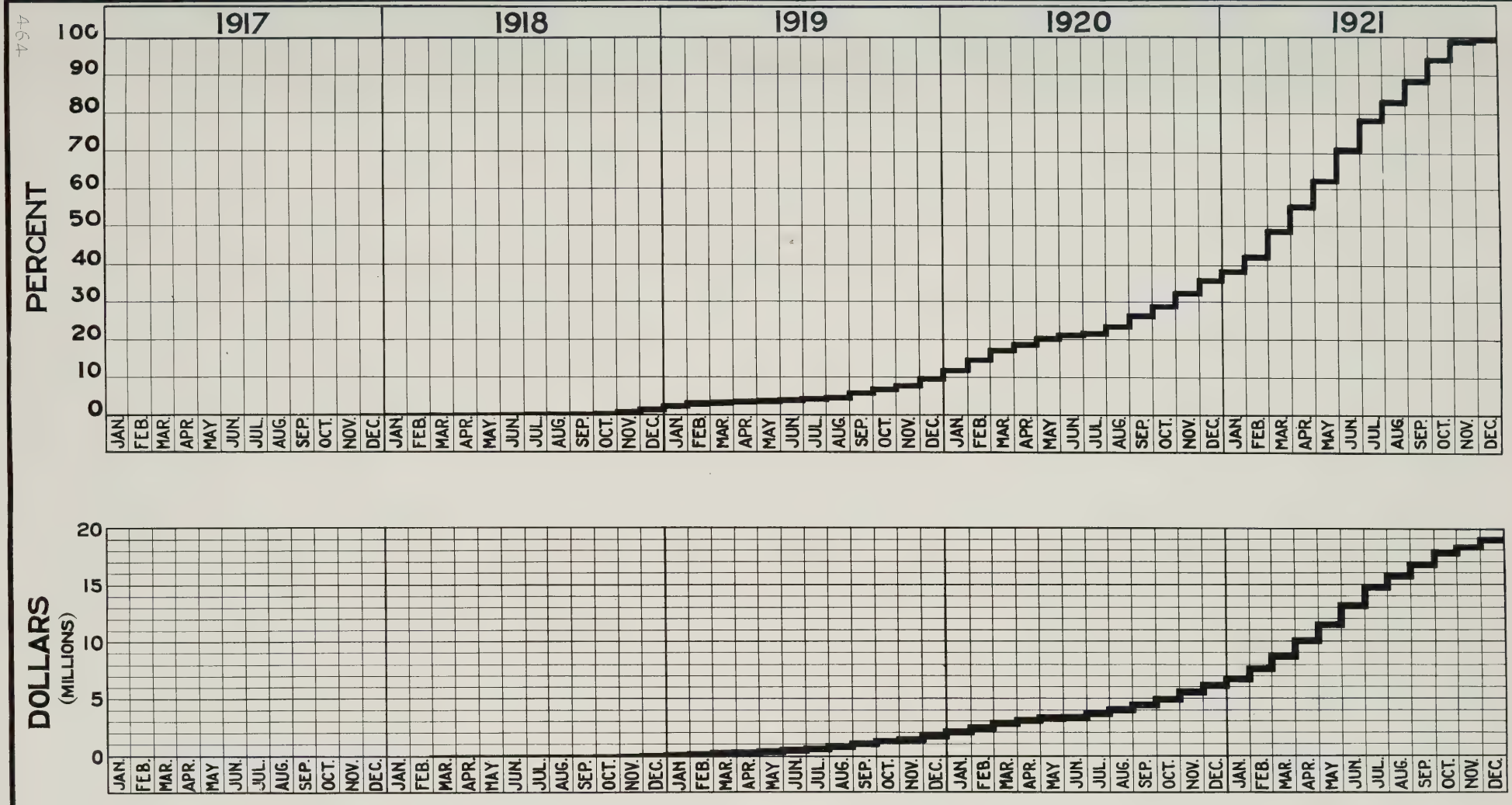
Section 24

SUMMARY OF COSTS

As previously stated our Consulting Engineer has prepared a report entitled "Chapter K - Costs, Analysis of Expenditures to March 31, 1922". This document deals in a most comprehensive and detailed way with all of the expenditures made on the work and almost any detail desired may be obtained by referring to it.

On page 128 we include a diagram showing the total expenditure on the project to March 31st, 1922. From this diagram it will be noted that the costs as at that date amount to a net total of $62,182,623.65 which total is subdivided under seventeen main headings. The striking feature about this diagram is that it shows the relative importance of the expenditure made on the canal proper in comparison with the whole Development. Out of a total of over $62,000,000 nearly $36,000,000 was expended on this portion of the work.


1917
1918
1919
1920
1921
PERCENT
100
90
80
70
60
50
40
30
20
10
0
JAN. FEB. MAR. APR. MAY JUN. JUL. AUG. SEP. OCT. NOV. DEC.
DOLLARS
(MILLIONS)
10
9
8
7
6
5
4
3
2
1
0
HYDRO-ELECTRIC INQUIRY COMMISSION
W. D. GREGORY, CHAIRMAN
QUEENSTON-CHIPPAWA POWER DEVELOPMENT
PROGRESS CHART FOR EARTH EXCAVATION IN INTAKE, CANAL, FOREBAY AND POWER HOUSE
Toronto, May 3rd, 1923. Made by W.S.D. Checked by W.J.F.
WALTER J. FRANCIS & COMPANY
CONSULTING ENGINEERS



HYDRO-ELECTRIC INQUIRY COMMISSION

W. D. GREGORY, CHAIRMAN

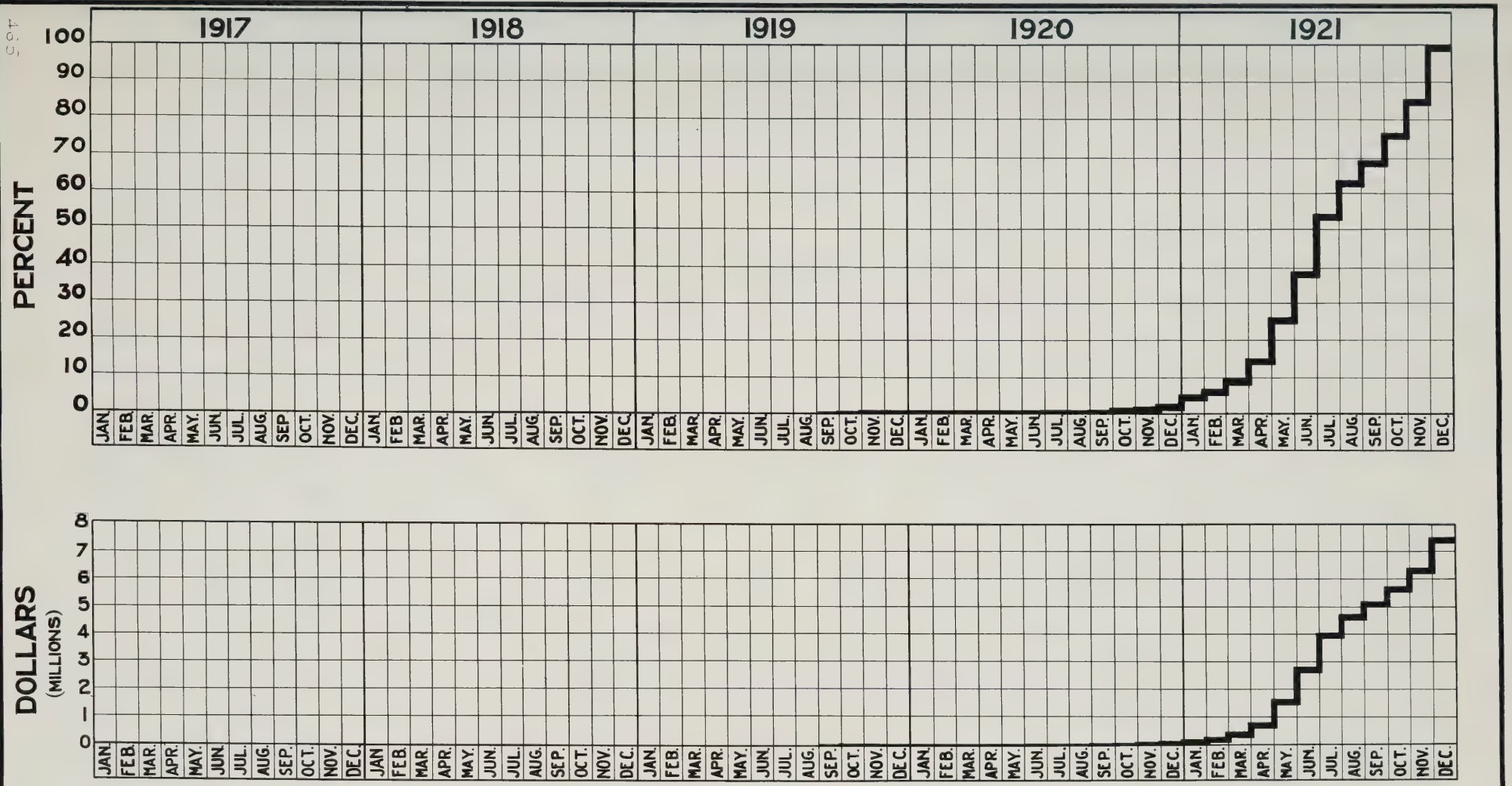
QUEENSTON-CHIPPAWA POWER DEVELOPMENT

PROGRESS CHART FOR ROCK EXCAVATION IN CANAL, FOREBAY AND POWER HOUSE

Toronto, May 3rd, 1923. Made by C.G.D. Checked by W.J.F.

WALTER J. FRANCIS & COMPANY

CONSULTING ENGINEERS



HYDRO-ELECTRIC INQUIRY COMMISSION

W. D. GREGORY, CHAIRMAN

QUEENSTON-CHIPPAWA POWER DEVELOPMENT

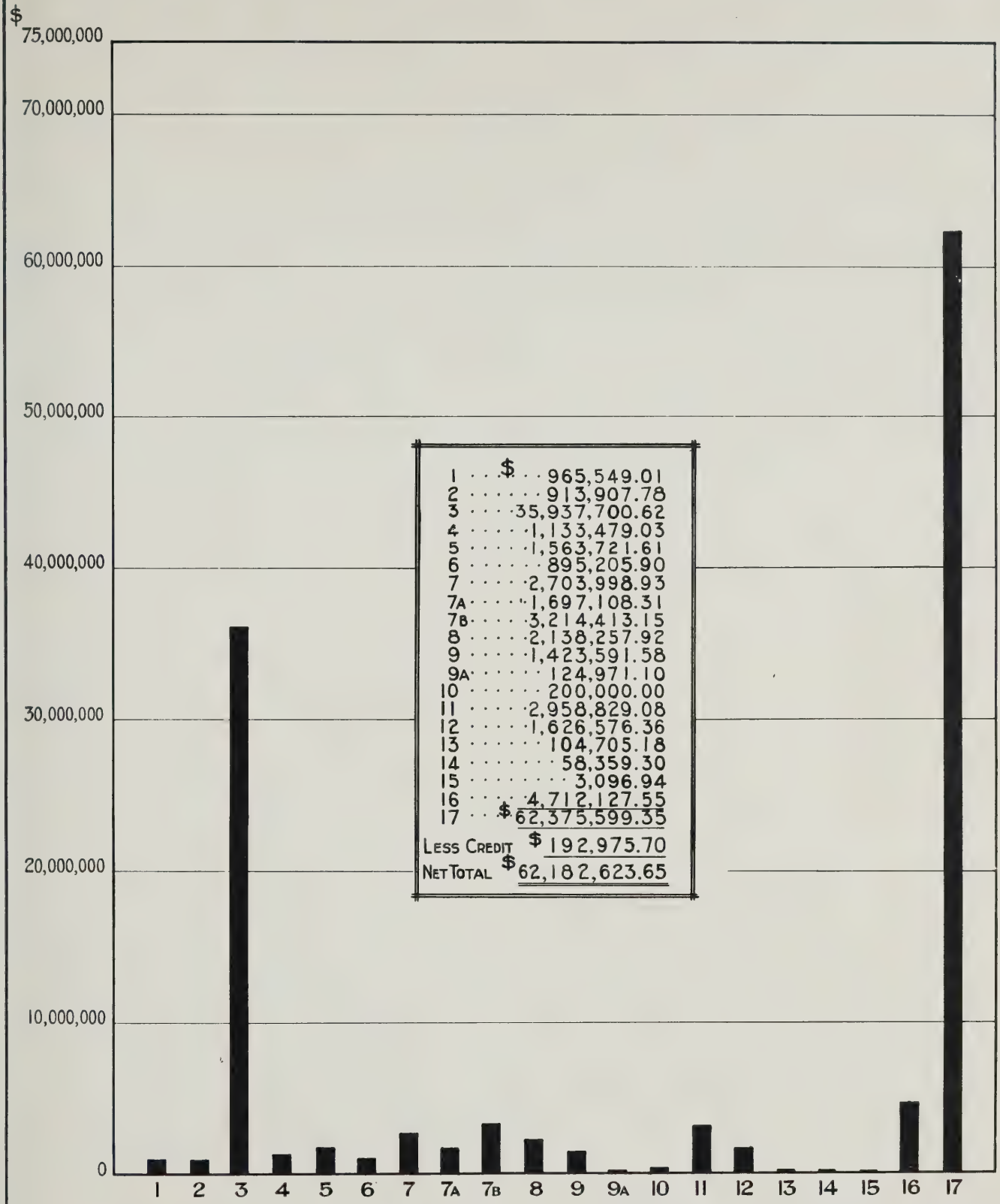
PROGRESS CHART FOR CONCRETE WORK IN CANAL AND FOREBAY

Toronto, May 3rd, 1923. Made by W.S.D. Checked by [illegible]

WALTER J. FRANCIS & COMPANY

CONSULTING ENGINEERS

127



1	$	965,549.01
2		913,907.78
3		35,937,700.62
4		1,133,479.03
5		1,563,721.61
6		895,205.90
7		2,703,998.93
7A		1,697,108.31
7B		3,214,413.15
8		2,138,257.92
9		1,423,591.58
9A		124,971.10
10		200,000.00
11		2,958,829.08
12		1,626,576.36
13		104,705.18
14		58,359.30
15		3,096.94
16		4,712,127.55
17	$	62,375,599.35
Less Credit	$	192,975.70
Net Total	$	62,182,623.65

1 Intake
2 River
3 Canal
4 Forebay
5 Screen House
6 Penstocks
7 Power House
7A Hydraulic Machinery
7B Electrical Generation
8 Bridges
9 Right-of-Way
9A Miscellaneous
10 Queenston-Power House Ry.
11 Plant Salvage
12 Stores
13 Expenditures
14 Sales and Work Orders
15 Suspense Account
16 Bond Interest
17 Gross Total Cost

Hydro-Electric Inquiry Commission
W. D. Gregory, Chairman
Queenston-Chippawa Power Development
Cost by Construction Elements

TOTAL EXPENDITURE ON PROJECT

To March 31st 1922
Toronto, May 2nd., 1923, Made by [illegible] Checked by [illegible]
Walter J. Francis & Company
Consulting Engineers

In view of the fact that the Commission in carrying out this work itself, had necessarily to include items for owner's overheads and financing costs, in addition to overhead costs and construction interest which would be incidental to a contractor's cost, if the work had been let by contract, our Consulting Engineer has made an analysis giving the final unit costs of the principal items of the work, namely earth excavation and rock excavation and concrete on two basis which may be termed "Contractor's Cost" and "Owner's Cost". In dealing with this matter the following paragraph and table of unit costs are included direct from our Consulting Engineer's report, pages K-104 and K-105:

> "The [following] analysis gives the unit costs derived from a consideration of the quantities for the principal classifications of work and the total costs thereof, first, on the usual basis of the costs to a general contractor carrying out the work, and, second, to the owner by the addition of the administrative field overhead and the head office overhead costs not ordinarily borne by a contractor. The first case is given in dollars per cubic yard of completed work in the column marked 'A' below, which embraces 'Direct Costs', 'Field Service Costs' and 'Field Overhead Costs' .....; while the second case is given in similar terms in the column marked 'B', which in addition to the costs contained in column 'A' embraces 'Administrative Field Overhead Costs' and 'Head Office Overhead Costs' ....."

"The (Cullenstey) analysis gives the unit costs involved from a quantification of the quantities for the principal classifications of work and the total costs thereof, first, on the annual basis of the costs to a general contractor carrying out his work, and, secondly, to the owner by the addition of the administrative field overhead and the home office overhead costs normally borne by a contractor. The first case is given in dollars per cubic yard of completed work in the column marked 'A' below, which embraces 'Direct Costs', 'Field Overhead Costs' and 'Final Overhead Costs', while the second case is given in similar terms in the column marked 'B', which in addition is the unit applicable to column 'A' adjusted for 'Administrative Plant Overhead Costs' and 'Head Office Overhead Costs' ..... ."

COPY

Committee Members' 1947

Graph and table of unit costs are included direct from our "Owner's Cost". In dealing with this portion [illegible] memorandum on the basis which may be termed "contractor's type" [illegible] time of his work, namely such quantities and unit [illegible] had been no analysis given for final unit costs of the principal case, if the work had been let by contract, our Consulting Engineer construction interest which would be included to a contractor's overheads and financing costs, in addition to overhead costs and out this work itself, had necessarily to include items for owner's

In view of the fact that the foundation is carrying

Derived Unit Costs of the Principal Classifications of Work

Work and Location of Same	Unit Costs in Dollars per Cubic Yard Column "A" "Contractor's Cost"	Column "B" "Owner's Cost"
Earth Excavation Work:		
Intake	$0.7645	$0.8059
Welland River	0.7178	0.7559
Canal	0.8087	0.8504
Canal Dredging	0.7566	0.7952
Forebay	0.5056	0.5301
Screen House	1.2646	1.3174
Power House	0.8782	0.9316
Average of all Earth Excavation Work	0.7924	0.8323
Rock Excavation Work:		
Canal	3.5635	3.7580
Forebay	1.6829	1.7611
Screen House	3.6788	3.8803
Penstocks	9.3318	9.9128
Power House	3.2512	3.5196
Average of all Rock Excavation Work	3.3752	3.5647
Concrete Work:		
Plain Concrete:		
Canal Lining	21.5296	22.9704
Forebay	28.0318	30.3328
Penstocks	19.8362	22.0369
Power House	30.1969	33.7597
Average of all Plain Concrete Work	22.5370	24.2412
Reinforced Concrete:		
Screen House	35.2118	38.8018
Average of all Reinforced Concrete Work	35.2118	38.8018

The relationship that these actual costs bear to the costs estimated by the Commission's engineers in estimates prepared by them from

time to time will be discussed in detail later in this report, but they are given here as a matter of record as they come within the subject of "Analysis of Expenditures".

Total Cost to complete

Out of the general question of costs naturally arises a discussion as to what will be the ultimate cost of the whole Development, when completed. In this connection the question referred to this Commission in the Letters Patent, being No. 3, reads as follows:

"The total cost when completed of the Queenston-Chippawa Power Development,
(a) With five units installed.
(b) With units installed to the full capacity of the canal.

In giving an answer to Question No. 3, it is to be borne in mind that any figure submitted is necessarily the result of the compilation of an estimate based upon expenditures already made and an estimate of the cost of what will be required to complete the work yet to be undertaken. The figures herewith submitted then, cannot be taken as an exact representation of cost, but our Consulting Engineer has carefully examined the work yet to be completed and has satisfied himself that these figures represent as nearly as possible, actual cost.

Answer to Question 3(a)

The total cost of the Queenston-Chippawa Power Development up to the completion of five units as nearly as can be determined is $63,654,296.49. This figure includes the whole of the completed canal and the intake as well as other portions of the Development which will be used in conjunction with the units to be subsequently installed. It is impossible to subdivide

the work so as to make the cost applicable to the five units only. Unit costs such as capital cost per horse-power, cannot be definitely derived from the above figures, and are obtainable only by considering the total cost of the fully completed Development.

Answer to Question 3(b)

The estimated cost of the Queenston-Chippewa Power Development with units installed to the full capacity of the canal is $62,483,914.00. This figure is derived by considering the expenditures made to date, adding thereto the estimated cost for completion and deducting therefrom the estimated salvage value of the construction plant, stores on hand and so forth, but not deducting anything for lands purchased over and above present requirements.

The expenditures in connection with the Development up to September 30th, 1923, including $2,019.14 for investigation for future development, as shown by the records of the Commission is $66,795,811.53 after making deduction for the estimated salvage. The total is arrived at by completed records up to August 31st, 1923, amounting to $66,378,811.53, together with estimated expenditures during September 1923 amounting to $417,000.00.

Memo by WJ?.

Water

PART VI - CAPACITY OF DEVELOPMENT

Section 25

G E N E R A L

In Section 24 we have dealt with the question of capital expenditures, and have indicated what the total cost of the Development will be when completed. The cost of the Development and its capacity are more or less complementary to each other and the two must be considered together if the true economics of the Development are to be understood.

In order to submit reliable information relative to the actual capacity of the Development and the power which would be made available with the plant in operation, our Consulting Engineer was instructed to determine, as closely as possible, the carrying capacity of the canal and the actual output of electrical energy available from the units at present installed, and from this information to derive, as closely as possible, the commercial output of the plant under various conditions. In connection with this matter, Mr. Walter J. Francis has prepared an exhaustive report entitled "Chapter D - Power Available". His studies on the subject are comprehensive and in addition to carrying on actual tests of the plant as now in operation, conducting measurements and making physical examination and hydraulic studies of the several elements constituting the Development, he has carefully examined meteorological and other data available from the records of the plants which have been in operation over a great number of years.

The determination of the power available from the Development involves primarily the determination of the elevation of the head waters, the carrying capacity of the Welland River, the carrying capacity of the canal, the determination of the elevation of the tail water, and the efficiency of the main units. In addition to these principal features, many minor hydraulic losses have to be considered, as, for example, the entrance head of the intake, the losses due to bends and to changes of section in the river and in the canal, the loss in entrance head at the screen house, the loss in the penstocks and in the Johnson valves, and in the draft tubes, as well as the losses in the turbines and in the electrical equipment. WJF. D-1.

The determination of available power for a given hydro-electric development generally includes amongst other factors watershed area, precipitation, evaporation and run-off, in order to arrive at the dependable flow, but none of the four enter into the problem in the usual way in connection with the Queenston-Chippawa Power Development. Lake Erie constitutes the immediate head water, and the discharge of the Great Lakes System down to and including Lake Erie, being the Niagara River, is the source of water supply for the Development. The proportion of water available for this and other developments is derived from the terms of an international agreement. Our Consulting Engineer states that, in his opinion, it is possible that the quantity of water divertible from the Niagara River for hydro-electric purposes may be increased in the near future by mutual consent of Canada and the United States, and that, in view of the advantages that would accrue, the elevation of the water surface, at which the diversion may be made, will be held more nearly constant or raised above the elevation WJF. D-2

now generally obtaining.

The Development is well located to take advantage of any future regulation in this respect and it is also advantageously situated in having its tailrace so closely adjacent to Lake Ontario. In connection with this particular matter, our Consulting Engineer states:

> "These features, briefly summed up as fixed and dependable elevations of head water and tail water, as well as definite flow, taken in conjunction, make the location of the Queenston-Chippawa Power Development highly advantageous from the viewpoint of hydraulics." WJF. D-2

After describing the manner in which the data and results contained in the report referred to above were obtained, our Consulting Engineer states as follows:

> "Taken as a whole, the results in the present volume under the general title of 'Power Available' have been obtained after a practically continuous study during sixteen months, followed as quickly as the exigencies of the situation would permit." WJF. D-3

Section 26

CAPACITY OF THE DEVELOPMENT

The general question referred to this Commission in connection with the above subject, being Question No. 4, is:

> "The continuous output capacity of the Queenston-Chippawa Power Development, under the conditions mentioned in Clause 3."

Clause 3 referred to is Question 3 contained in the Letters Patent, and the conditions referred to are Parts (a) and (b) of Question 3, which are as follows:

(a) With five units installed.
(b) With units installed to the full capacity of the canal.

Section A

Subject A Sub-Subsection

The reader's special interest in this Proposition is somewhat
also the above indicated. Refer Section Ref. 47, Int
[a] With care Impossible to the full ambiguity of the event.
[b] With this Impossible to the full ambiguity of the event.

Clause 3 referred to in Section 3 modifies it the Factors
2, which are as follows:

[1] With this Impossible to the full ambiguity of the event.
[2] With this Impossible to the full ambiguity of the event.

"Some Impossible, briefly enough to be fixed and Separable
alteration of Real Union and Exit Rate," is still a
Definite Plan, Union In Conjunction, make the Inertion of
the Impossible-Difficult Their Impossible Highly Improbable
then the Almighty is Optimistic."

Since Selecting the Course In Which the Exit and Penalty Sec-
tions In the Second Reference to Above were Combined, our Committee
Reserve Entity to Impose

"Since we a Right, the Inertia In the Present Allows Under
the Special Title Of 'Their Initiative' Below Them Obtained
after a Particularly Prominent Body During Either Under-
followed or Closely on the Alignment at the Situation
Real Power."

Section 24

Subject A Sub-Subsection

The Inertia Special material to this Proposition is somewhat
also the above Defined. Refer Section Ref. 47, Int

"The Existence Union Capacity at the Impossible-Difficult
Above Impossible, Apply the Position Continued In
Clause B."

Clause 3 referred to in Section 3 modifies it the Factors
2, which are as follows:

[1] With this Impossible to the full ambiguity of the event.
[2] With this Impossible to the full ambiguity of the event.

Clause explanation in this respect and it is also characteristic Situation

in having the failures so closely adjusted it less Impulse. It Impose-

then this this particular nature. Our Committee Impulse reason:

"Since Impulse, briefly enough to be fixed and Separable
alteration of Real Union and Exit Rate," is still a
Definite Plan, Union In Conjunction, make the Inertion of
the Impossible-Difficult Their Impossible Highly Improbable
then the Almighty is Optimistic."

The Impossible is well Imposed to take advantage of any

Capacity with Five Units Installed

To this part of Question No. 4 based upon the tests and studies which are recorded in our Consulting Engineer's report before referred to, the answer is:

"The continuous twenty-four hour output capacity of the Queenston-Chippawa Power Development with five units installed under normal operating conditions is 275,000 electrical horse-power."

Capacity with Units Installed to Full Capacity of the Canal

On the same basis as Question 4(a), answered above, the following statement is submitted in answer to Question 4(b):

"The estimated continuous twenty-four hour output capacity of the Queenston-Chippawa Power Development with units installed to the full capacity of the canal is 550,000 electrical horse-power."

Section 27

WATER AVAILABLE FOR DEVELOPMENT

A discussion of this question necessarily includes consideration of the conditions under which the Development will be operated by the Commission. As we have already shown in our report on the Niagara System, the Commission, in addition to the plant at Queenston, owns and operates two other large plants which also draw their water from the Niagara River, namely, the plants of The Ontario Power Company and the Electrical Development Company. Therefore, it is necessary to consider the operation of the Queenston-Chippawa plant not only as a unit by itself, but as one operated in conjunction with the two other plants just named.

The combined operations of these plants is fully discussed in

Chapter VIII

Plans for Improvement

A discussion of this question necessarily includes consideration of the conditions under which the improvements will be effected by the Commission. As we have already shown in our report on the Niagara Operations, in addition to the plant at Queenston, over one thousand horse power will also come daily water from the Niagara River, supplying the plants of the Ontario Power Company and the Electrical Development Company. Therefore, it is necessary to consider the operation of the Queenston plant not only as a unit by itself, but as one operated in connection with the two other plants just named.

The combined operations of these plants is fully discussed in

our Consulting Engineer's report entitled "Niagara System, Part II", and the matter is further discussed in this Commission's report entitled "Report on the Niagara System" and for detailed information we would refer you to these documents. In this report we will deal only with the broader question, namely, the water that is available for the Queenston-Chippawa plant under normal operating conditions and the power that can be developed from it.

The Letters Patent refers to this matter in Question 6, which reads:

> 6. (a) The quantity of water now available for use by means of the Queenston-Chippawa Canal;
>
> (b) The power that can be developed thereby in continuous output at the Queenston Power Station.

(a) The Quantity of Water now Available

The water now available for use by means of the Queenston-Chippawa Canal is derived from two sources, namely, the Welland River and the Niagara River.

The flow of the Welland River is comparatively small, and the concensus of opinion is that it may be considered to be less than 100 cubic feet per second at low water. The engineers of the Commission in their estimates used the figure of 50 cubic feet per second as the available flow from the Welland River, without allowing for its storage possibilities as pondage for a daily regulator in power plant operation.

The flow from the Niagara River is limited by the provisions of a treaty ratified May 5th, 1910, between Great Britain and the United States,

which treaty was to remain in force for five years, terminable thereafter on twelve months written notice by either party. No notice of termination has been given. Paragraph 4 of Article V of the Treaty says:

> "The United Kingdom or the Dominion of Canada, or the Province of Ontario, may authorize and permit the diversion within the Province of Ontario of the waters of said River above the Falls of Niagara, for power purposes, not exceeding in the aggregate a daily diversion at the rate of 36,000 cubic feet of water per second."

This paragraph apparently contemplates a variation in the rate of use of water for power purposes throughout different periods of the same day. This is in accordance with the usual practice of all hydro-electric power plants, wherein the rate of use of water varies throughout the twenty-four hours according to the load demands upon the plant. While it would be evidently unreasonable to interpret this clause as permitting the diversion of water at a rate four or five times the figure specified during a few hours of the day, it is quite reasonable, on the other hand, to permit of variations in the rate of use so as to conform with the ordinary conditions found in plants at Niagara Falls. The limits of variation in the rate of use of water differs from plant to plant, but a variation of 20% or even 25% above the average stated by the treaty is well within the bounds of reasonable interpretation. Such an interpretation would permit a total diversion on the Canadian side of the Niagara River for power purposes up to a figure of about 45,000 cubic feet per second during several hours of each day, provided the total diversion did not exceed "in the aggregate a daily diversion at the rate of 36,000 cubic feet of water per second."

The four existing hydro-electric power plants on the Canadian

side of the Niagara River, exclusive of the Queenston-Chippawa Power Development, were diverting under ordinary use, before the Queenston-Chippawa Power Development was built, an aggregate amount of 32,000 or 33,000 cubic feet of water per second, as nearly as can be determined. The Commission now owns or controls the Electrical Development Company plant and The Ontario Power Company plant, thus obtaining the opportunity of working these two plants in conjunction with the Queenston-Chippawa Power Development. The other two power plants, namely, the Canadian Niagara Power Company and the International Railway Company have water rights which are fixed by agreement and Orders-in-Council, so that the use of water by these two plants is defined and limited, but it is not under the control of the Commission. The maximum amount of water usable by these two plants together is variously estimated between 8,500 cubic feet per second and 9,800 cubic feet per second.

It is estimated that the most efficient use by the Commission of the Electrical Development Company plant and The Ontario Power Company plant would be at a combined output of about 250,000 electrical horse-power continuously, requiring an amount of water variously estimated between 17,200 cubic feet per second and 18,100 cubic feet per second.

With all four plants in operation under these circumstances the probable use of water is about 26,000 or 27,000 cubic feet per second. Deducting 27,000 cubic feet of water per second from the figure derived from the above interpretation of the provisions of the treaty, it is evident that about 18,000 cubic feet per second should be available for the operation of the Queenston-Chippawa Power Development.

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While not specifically referred to in any of the questions referred to this Commission in the Letters Patent, it is to be noted that the plant as at present built, and more particularly the canal, was designed to utilize 15,000 cubic feet of water per second. Tests conducted by our Consulting Engineer indicate that the expectations of the Commission's engineers in this respect will be exceeded and that it may be safely assumed that the canal will pass a flow of water totalling 18,000 cubic feet of water per second or more. It is apparent, therefore, that the canal is capable of passing the maximum amount of water, which our Consulting Engineer states should be available for the operation of the plant.

In discussing this matter, it is to be borne in mind that the statements just previously made largely depend upon what may be termed a practical interpretation of the terms of the treaty covering the diversion of water from the Niagara River. But no matter what the interpretation of the provisions of the agreement may be, it is to be remembered that even though the amount of water allotted to Canada be restricted to an overall maximum of 36,000 cubic feet of water per second, the Commission owning and operating The Ontario Power Company and the Electrical Development Company may, at its discretion, restrict the operation of these plants and utilize the water thus made available for the Queenston-Chippawa plant. It may be said, therefore, that the Commission is in a position to make sufficient water available for the full and complete operation of the Queenston-Chippawa plant, by regulating the operation of the two older plants. It seems reasonable to assume that it will follow this course, for not only has

the Queenston-Chippawa plant a very high operating efficiency as compared with the older plants, but one cubic foot of water used at the high head available at Queenston will develop twice as much power as the head available at the other plants.

The 100% advantage

Power that can be Developed by 18,000 cubic feet of water per second

The second part of Question 6 has already been dealt with in our answer to Question 4, but for the sake of completeness the following statement is submitted again. The power that can be developed by 18,000 cubic feet of water per second in continuous output at the Queenston-Chippawa Power Station is 550,000 electrical horse-power.

Section 28

COST OF POWER DEVELOPED

The Letters Patent refers to this matter in Question No. 7 which is:

> "In what manner and to what extent will the price of Niagara Power be affected, if at all, by the cost of the Queenston-Chippawa Development."

The Queenston-Chippawa Power Development commenced to deliver power to the Niagara System early in 1922, although undergoing adjustment and extension. In the same year the Commission took over the Toronto Power Company, including the plant of the Electrical Development Company and a steam plant in Toronto. In the same year the Commission decided to operate the plant of The Ontario Power Company "at cost", rather than to follow the former procedure of billing themselves with part of the power at the old contract rate and making a supplementary charge to cover the loss on the contract price.

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Taking all these factors into consideration, it is evident that 1922 is a transition year. Several years may elapse before the whole combination of power plants will have reached a condition of stability as regards costs and operating conditions. Therefore the comparison of power prices must be made with the end of 1921 as the dividing line, the period prior to that date being before the Queenston-Chippawa Power Development was sufficiently far advanced to be considered as a power producer

The average price which the Commission paid for Niagara power from all sources of supply from 1911 to 1921, inclusive, is as follows: 1911, $9.40; 1912, $9.37; 1913, $9.00; 1914, $9.00; 1915, $9.00; 1916, $9.46; 1917, $10.11; 1918, $10.07; 1919, $10.25; 1920, $11.36; 1921, $12.55. All the figures are in dollars per horse-power purchased per annum. In 1922 the average cost is stated to have been $16.55 per horse-power per annum, but this figure includes a block of 73,966 horse-power from the Queenston-Chippawa Power Development, billed at the arbitrary figure of $20.00 per horse-power per annum.

To find the effect of the Development on the price of Niagara power it is necessary to estimate the cost of power from each of the three sources of supply at Niagara Falls, namely The Ontario Power Company plant, the Electrical Development Company plant and the Queenston-Chippawa Power Development, and to ascertain the proportion of the total power demand supplied from each of the three sources.

The output capacity of The Ontario Power Company plant under maximum conditions is about 195,000 horse-power, but the probable most

efficient point of operation is with an output of about 150,000 horse-power. Similarly, the Electrical Development Company plant could produce about 146,000 horse-power, but its probable most efficient use is at an output of about 100,000 horse-power. There is also the steam reserve plant at Toronto, which although not operating is being maintained as an emergency power reserve, and the fixed charges should be billed against power generation.

The cost of Niagara power at the switchboard at Niagara Falls will be made up in the future of the operating costs and fixed charges on the four power generating plants above mentioned.

Assuming a fixed output of 250,000 horse-power under normal conditions from the combined operation of The Ontario Power Company plant and the Electrical Development Company plant, the balance of the demand being supplied from the Queenston-Chippawa Power Development, the figures are as follows:

(1) The Ontario Power Company Plant

Total annual operating costs and fixed charges, between (a) $2,000,000 and (b) $2,200,000, equivalent respectively to $13.50 and $15.00 per horse-power per annum, with an output of 150,000 horse-power.

(2) Electrical Development Company Plant

Total annual operating costs and fixed charges, between (a) $1,200,000 and (b) $1,300,000, equivalent respectively to $12.00 and $13.00 per horse-power per annum, with an output of 100,000 horse-power.

(3) Queenston-Chippewa Power Development

Maximum Plant Output, H. P. (No spare machines)	Annual Operating Costs and Fixed Charges		Cost per H. P. per Annum	
	Possible Minimum (a)	Possible Maximum (b)	Possible Minimum	Possible Maximum
300,000	$4,300,000	$4,450,000	$14.30	$14.85
350,000	4,500,000	4,750,000	12.85	13.60
400,000	4,750,000	5,100,000	11.90	12.75
450,000	5,200,000	5,500,000	11.55	12.25
500,000	5,800,000	6,150,000	11.60	12.30
550,000	6,500,000	6,900,000	11.80	12.55

In the above tables the mark (a) denotes estimates based on figures of the Hydro-Electric Power Commission, and the mark (b) denotes figures in which allowances have been made for contingencies, additional reserve for renewals, and so forth, sufficient to cover maximum requirements.

(4) Toronto Steam Plant

The total annual fixed charges should probably be between $120,000 and $150,000 annually without output and under normal conditions.

On the above assumptions the weighted average cost of Niagara power at the switchboard at Niagara Falls will be between the following limits:

Combined Output H.P. (all plants)	Total Annual Operating Costs and Fixed Charges		Annual Cost of Power per Horse-Power	
	Possible Minimum (a)	Possible Maximum (b)	Possible Minimum	Possible Maximum
550,000	$7,620,000	$8,100,000	$13.90	$14.75
600,000	7,820,000	8,400,000	13.05	14.00
650,000	8,070,000	8,750,000	12.40	13.45
700,000	8,520,000	9,150,000	12.15	13.10
750,000	9,120,000	9,800,000	12.15	13.10
800,000	9,820,000	10,550,000	12.30	13.20

From these figures it will be seen that the price of Niagara power to the Commission after 1921 will be affected very little in one sense, and very materially in another, by the installation of the Development.

The figures from 1911 to 1921, inclusive, show that from 1915 the price has been steadily rising. In 1921 it was $12.55 per horse-power per annum. Omitting 1922 as the first of the transition years, the figures for which are subject to adjustment, the existing present conditions are next to be considered. These show weighted average costs, with 550,000 horse-power available at best efficiency, ranging between $13.90 and $14.75 per horse-power, but as the power generated or billed in 1923 was probably not 550,000 horse-power, but some smaller figure, the total annual costs must be divided by the proper horse-power figure to get the average cost price. If this figure were 500,000 horse-power, the average cost would be about $25.00, and similarly if it were 400,000 horse-power, the cost price per horse-power would be $19.00 or $20.00, and so on for any other figure of output. It is reasonable to assume that the output for the year 1923 will lie between these limits. The figures in the above table apply, therefore, only on the assumption that there is a constant output of 250,000 horse-power from the plant of The Ontario Power Company and from the plant of the Electrical Development Company combined, and that each stage of the Queenston-Chippawa Power Development is fully loaded before capital expenditures on succeeding stages of development are made and the annual charges thereon carried by the revenues from operation.

It appears likely that after 1924 or 1925 this condition may be substantially realized, and that for the later stages of development the

weighted average cost price of Niagara Power will be about $12.50 or $13.00 per horse-power at the switchboard, or about the same as in 1921. Until this condition will have been realized, the annual costs per horse-power must be found by dividing the total costs by the total horse-power billed.

Another aspect of the situation should also be mentioned. If the Queenston-Chippawa Power Development had not been made it would have been necessary to purchase power or generate it elsewhere to supply the load demands. The records show that the purchase price of power from other sources was increasing after 1916, and that in 1920, 1921 and 1922 the purchase price of power required in excess of existing contract arrangements had reached the figure of $18.00 per horse-power per annum. Other contracts for power supply from the Canadian Niagara Power Company were made by the Commission for the account of The Ontario Power Company of Niagara Falls, one for 9,000 horse-power for two years ending January 31st, 1922, at $18.00 per horse-power per annum, and several other contracts aggregating about 30,000 horse-power and discontinued May 31st, 1922, at $16.20 per horse-power per annum, payable in United States funds, approximating $18.00 in Canadian funds at the time. After the Queenston-Chippawa Power Development was in Operation, a contract to purchase 20,000 horse-power at $15.00 per horse-power per annum from the Canadian Niagara Power Company was made by the Commission in December, 1922, and this contract will expire on May 1st, 1930. The supply available from such outside sources as the above was not and is not sufficient to serve the needs of the various customers who have since demanded power service. The Queenston-

Chippewa Power Development has supplied the demand, and if the estimated costs are substantially realised in the future, it will show very large savings over the probable price of purchasable power.

By itself, the Development would doubtless produce power in its various stages of development at a cost price of $14.50 or $15.00 per horse-power per annum with five units fully loaded, which would be reduced to $12.00 or $13.00 per horse-power per annum with the full development operating under normal conditions and free from operating difficulties.

It is evident that The Ontario Power Company plant at 150,000 horse-power output would produce power at $13.50 to $15.00 per horse-power per annum based on a capitalization of about $25,000,000, and that the Electrical Development Company plant at an output of 100,000 horse-power would produce power at $12.00 or $13.00 per horse-power per annum based on a capitalization of about $13,000,000.

With 190,000 horse-power output the costs at The Ontario Power Company plant would be about $11.00 or $12.00 per horse-power per annum, and, similarly, if the Electrical Development Company plant were operating with 146,000 horse-power output the costs would be $8.50 or $9.00 per horse-power per annum.

If these plants were operated at these outputs, however, the capacity of the Development would be limited to about 350,000 horse-power with the present water rights, and the combined weighted average cost would be from $11.50 to $12.25 per horse-power per annum.

Assuming unrestricted water rights for the present plants with full capacity installed, 27,000 cubic feet of water per second would produce about 540,000 horse-power from The Ontario Power Company plant and the Electrical Development Company plant combined, at a total annual cost between $3,400,000 and $3,800,000, these total figures being equivalent to $10.00 per horse-power per annum, and $11.20 per horse-power per annum, respectively. The Queenston-Chippewa Power Development could probably produce 550,000 horse-power with 18,000 cubic feet per second of water at a cost of $12.00 or $13.00 per horse-power per annum. The weighted average of these figures would be about 900,000 horse-power at $11.00 to $12.00 per horse-power per annum, and the total water required for these three plants would be about 45,000 cubic feet per second. Adding the water used by the Canadian Niagara Power Company and by the International Railway Company, the total water diversion on the Canadian side would have to be about 55,000 cubic feet per second and the total power produced would be about 1,000,000 horse-power.

Other Factors Affecting Cost of Power

The foregoing statement is what may be termed a comprehensive answer to Question No. 7 contained in the Letters Patent and the figures quoted have, in the first instance, been arrived at by using estimates submitted to our Consulting Engineer by the engineers of the Commission. These figures have in turn been analysed by our Consulting Engineer and as stated under the second analysis given, he has revised the estimates submitted by the engineers of the Commission to a basis which makes additional allowance for contingencies, reserve for renewals and so forth, sufficient to cover maximum requirements. It is pointed out in this

connection that the estimates submitted by the engineers of the Commission did not include any item whatsoever for contingencies and that the rate in respect of reserve for renewals is somewhat less than that used herein.

In our opinion, basis (b) should be considered for use by the Commission in setting up operating costs in respect of this Development.

In our report on the Niagara System, we have dealt at some length with the favoured condition which the Greater Niagara System enjoys on account of the extended sinking fund period on the Queenston-Chippawa Development, and a similar condition in connection with the bonded indebtedness of the power companies which are owned and operated by the Commission. According to the figures arrived at by our Accountants, we have shown that this advantage in terms of dollars and cents will amount to about $800,000 annually.

Owing to the complications involved, it is impossible to compute with accuracy the extent to which the annual cost per horse-power to municipalities on the Greater Niagara System would be increased if sinking funds for the power plants at Niagara were established on a thirty-year basis contemplated by the Power Commission Act. Suffice it to say, however, that the increase would be considerable.

Taking into account the completed condition of the Queenston-Chippawa Power Development, capable of delivering 550,000 electrical horse-power, and assuming that the Electrical Development Company and The Ontario Power Company are operating in conjunction with the Queenston plant, giving a total output capacity of about 800,000 horse-power, the extra yearly charges which would be added, if the operation of these

plants placed on the same basis as the plants in other systems, would amount to the sum just quoted, namely, $800,000, less a comparatively small amount applicable to the transmission lines and other equipment taken over in connection with the "Clean-up" deal.

It follows, therefore, that, if the horse-power billed to the Greater Niagara System remained constant at 800,000 horse-power, the rates applicable would be increased by $1.00 per horse-power. Having regard to the fact, however, that the horse-power billed will be some amount less than this, the extra cost per horse-power will be proportionately increased.

Referring to another part of this report wherein is quoted statements from a letter of September 13th, 1915, by Sir Adam Beck submitted to the Premier, the following passage should be observed:

> "It was found that on the basis of an ultimate 300,000 h.p. capacity for the permanent works, and with 100,000 h.p. equipment installed, the development could be made for $10,500,000 with an annual charge of approximately $944,600.00 per annum, including operation, interest, sinking fund, maintenance and all other operating charges, or an equivalent of $9.44 per h.p. per annum for 100,000 h.p. without depreciation and sinking fund, the annual charges for 100,000 h.p. would be $7.00 and for 75,000 h.p.,- $9.20.
>
> "Estimates were also prepared to cover capacities up to 200,000 and 300,000 h.p. which indicate that 200,000 h.p. can be developed at a price not exceeding $7.00 and 300,000 h.p. at a price not exceeding $6.00 per annum including interest, sinking fund and depreciation charges."

Now it will be noted that at the time this statement was made a maximum development of 300,000 horse-power was contemplated and it was predicted that the price per horse-power would not exceed $6.00 including

all charges. At that time the Commission was figuring interest at 5%. Since the above statement was made interest charges have increased, and are now being figured at about 6%. On the other hand the $6.00 rate is figured on a thirty-year sinking fund basis equivalent to an annual charge of about 1.8% on the capital invested. The sinking fund now figured by the Commission is on a forty-year basis which reduces the annual charge from 1.8% to 1%, correspondingly reducing the annual cost of power. Depreciation charges, commonly known as reserve for renewals, were figured upon a much higher basis in 1915 than at the present time. In 1915, they were probably more than twice as great as are now being used by the Commission. It would appear that any advantage gained by decreasing yearly sinking fund amounts and depreciation charges is approximately offset by the increase in interest rate. It may be considered, therefore, that if the cost of power in 1915 was $6.00 per horse-power per annum, it would be practically the same figure at the present time if construction costs had been accurately estimated in the first instance. Construction costs of all kinds increased enormously during the period from 1915 to 1921 when the Queenston-Chippawa Power Development was being made, and, generally speaking, the purchasing power of a dollar towards the end of that period was about half of that of 1915. It is therefore unfair to compare an estimated cost of $6.00 per horse-power made in 1915 with present costs unless the general inflation of prices be taken into consideration together with the specific local conditions found during the construction of the Development.

The fact remains that the cost of power from the Chippawa plant will actually be between $15.00 per horse-power per annum at present and about $12.50 or $13.00 per horse-power per annum in the future when the completed plant is operating at full load.

On the basis of actual conditions, it might be stated that the effect of the increased construction costs after 1915 is that the actual cost of power from the Queenston-Chippewa Power Development is between two and two and one-half times the estimated figure made public by Sir Adam Beck in his letter quoted above.

There is another matter that should be kept in mind when making these comparisons; namely, that the estimate of capital cost made in 1915, on which the estimate of the cost per horse-power was based, does not represent a plant of the capacity as built, nor does it in many respects represent the unit costs as used in Estimate No. 2 of 1917, which was the estimate under which the construction was proceeded with. On the other hand, as far as we have been able to learn, the statement made by Sir Adam Beck in his letter of September 13th, 1915, regarding the annual cost per horse-power of energy from the Development contains the only figures which were given publicity at the time the Development was under consideration.

We have shown in our report on the Niagara System that on January 1st, 1917, a vote was submitted to the ratepayers of over 70 municipalities in the Niagara System, asking for the endorsation of a plan whereby the Commission would be authorized to acquire operating companies or construct developments necessary for the supply of electrical energy to the Niagara System. The figures quoted in the letter of September 13th, 1915, above referred to, were undoubtedly in the minds of the people who voted on this question, and, as we have stated, little or no publicity was given to any other figures subsequent to that time.

Effect of Capital Costs on
Annual Cost per Horse-Power

In a former report we state that there are very few, if any, undertakings in which interest charges on the capital investment play so important a part in annual cost as in the generation of electrical energy. In connection with the same subject, we show that on the basis of the estimates of the Commission interest on the capital invested represents approximately 70% of all the charges entering into the annual cost of generating power in the combined plants at Niagara.

Sinking fund is the next important item and represents approximately 13% of the cost, using a forty-year sinking fund period. Therefore, the remaining 17% is distributed amongst operation, maintenance, depreciation and so forth. From this it is apparent that the capital cost is the direct regulator of the annual cost per horse-power. Putting this fact in its simplest terms it may be stated that the capital cost per horse-power directly regulates the annual cost per horse-power. The extent to which this statement may be applied varies for different conditions, but in the case of the Queenston-Chippawa Power Development it applies more forcibly than in any other development operated by the Commission. In another section of this report we have set forth all estimates prepared by the engineers of the Commission or by consultants employed by it from June 23rd, 1915, to January, 1923. For purposes of convenience we repeat certain of the information contained in that table, as follows:

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Date of Estimate	Nominal Installation Horse-Power	Canal Capacity Approximately cu.ft. per sec.	Horse-Power	Total Amount of Estimate in Dollars	Approximate Capital Cost per Horse-Power
(a) June 23/15	100,000	6,550	Varying	10,410,233	104*
(b) Jan. 5/16	200,000	6,550	Varying	13,149,803	65
(c) Nov. 27/17	300,000	10,000	300,000	24,316,815	81
(d) Feb. 5/18	300,000	10,000	300,000	24,000,000	80
(e) Jan. 5/19	300,000	15,000	500,000	25,102,915	84*
(f) Late in 1919	300,000	15,000	500,000	27,025,635	90*
(g) Jan. 29/23	300,000	15,000	500,000	64,370,180	214*
(h) Jan. 29/23	500,000	15,000	500,000	74,677,367	149
(i) Jan. 29/23	550,000	15,000	550,000	80,729,014	147

The figures in the column headed "Approximate Capital Cost per Horse-Power" are arrived at by dividing the total amount of estimate in dollars by the nominal installation horse-power. In cases where the installation is only part of the capacity of the development as a whole, the figures in the column headed "Approximate Capital Cost per Horse-Power" are marked with a star, thus *, and are not comparable amongst themselves nor with those not so designated with a star. It will thus be seen that there are in the table given above five cases on a corresponding basis.

As a matter of fact, the last estimate bearing date January 29th, 1923, lettered (i), above, was again revised on February 21st, 1923, the estimated capital cost being given to our Consulting Engineer as $82,483,914. Dividing this by the nominal installation horse-power, 550,000, we get an approximate capital cost per horse-power of $150.00. Accepting this as a final figure, and comparing it with the estimates in three of the cases in which they are comparable, we get the following:

Date of Departure	Destination	Fare (Economy Class)	Fare (1st Class)	Total Expenditure (Economy Class)	Total Expenditure (1st Class)	Approximate Capital Cost per Person
[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]	[illegible]

1. Increase of final cost over estimate of January 5th, 1916 ..... $85.00 per h.p. or 131%.

2. Increase of final cost over estimate of November 27th, 1917 ..... $69.00 per h.p. or 85%.

3. Increase of final cost over estimate of February 5th, 1918 ..... $70.00 per h.p. or 88%.

We have previously shown that the annual cost per horse-power to the Niagara System will be somewhat more than twice the amount originally estimated upon in 1915. Comparing this ratio of increase with the ratio of increase in capital cost per horse-power developed, it will be noted that while the ratio is not greatly different, the ratio of increase in the capital cost per horse-power is less than the ratio of increase in the annual cost per horse-power. It is quite natural that this is so, for the development as now being constructed has nearly twice the capacity of that estimated upon in 1917, but the works necessary to obtain this capacity are far from being twice the extent of those contemplated in the 1917 estimate. It may be stated generally that the capital cost per horse-power developed decreases within certain limits as the capacity increases.

In another report we have stated that the annual cost of power bears a fairly definite percentage ratio to the capital cost per horse-power developed, varying probably between 8% and 14%. In this report we have shown that the annual cost of power from the Queenston-Chippawa Power Development when fully loaded will vary from $12.50 to about $14.00 per horse-power at the bus-bars. It follows, therefore, that, in this Development, the annual cost of power is between 8% and 9% of the capital cost per horse-power developed.

With this fact in mind it is interesting to observe the effect

that an increase in the capital cost would have on the annual cost of power. Assuming that a plant capable of developing 550,000 horse-power at a capital cost of $82,000,000 should have cost $11,000,000,less, or $71,000,000 under ordinary circumstances, the excess cost of $11,000,000 represents $20.00 capital cost per horse-power for a 550,000 horse-power plant. Assuming that the annual cost per horse-power represents about 9% of the capital cost of developing, the price of power would be affected to the extent of only $1.80 per horse-power per annum. It will, therefore, be noted that a development of this character might have an increase of many millions of dollars in capital cost without affecting to a very marked extent the annual cost per horse-power.

There is still another view of this matter which should be taken into consideration, namely, that our analysis has been based upon the sale of power at the bus-bars of the generating station. This power is in reality distributed to the municipalities, the local authorities of which sell it on a retail basis to their customers. As the sale of power increases and as its consumption is spread over a variety of uses, the value of the diversity factor increases, and the municipalities may, and usually do, receive revenue from the sale of much greater amounts of power than they actually purchase from the Commission. Therefore, any excesses or increases in cost of power billed them by the Commission may be entirely absorbed or offset when diversity is taken into consideration. Nevertheless, if there is an excess or an unwarranted increase in the cost of power, the economic loss still exists and the excess

expenditure can never be recovered.

Summary

We have shown that the increase in the annual cost of power delivered from the Queenston-Chippawa Power Development varies almost in the same ratio as the increase of actual over estimated capital cost. We will set forth in a later part of this report our opinion as to what the actual cost should have been, but speaking generally it may be stated now that the increases in the cost of power to the Niagara System over the cost predicted in 1915 are directly caused by the increased capital cost of the work, which increase is largely due to the unusual way in which the work was carried out, and to the conditions prevailing at that time. It may also be stated that, even when work of this nature costs a great deal more than it should, the effect on the annual cost of power is not so great as might be expected.